aluminum film, and the aluminum–glass bond were strong enough to pluck nuggets of glass from the microscope slides.

The production of adherent films requires considerable care. An outline of the glass preparation and evaporation conditions is given. Only four runs or cases are here reported but adherent films were produced on many other occasions at will, without measuring film strengths.

If the assumption of a metal oxide or other transition layer is correct, the production of an adherent film begins with the removal of all foreign matter including gases from the surface of the glass. The work of Langmuir, Manley,[4] and others on the adsorption of gases on solid surfaces shows that the strong bonding forces of a substrate do not extend beyond one monolayer of gas upon the surface. Thus the surface must be cleaned before deposition so that at most only a small fraction of a monolayer remains. A high vacuum is sufficient to remove the upper layers of gas and in accord with the several adsorption isotherms of Langmuir, Pashley,[4] and others, heating in a vacuum should partially remove the monolayer.

The surface should remain clean for some time while a proper mixture of metal vapor and oxygen arrive at the glass surface. After several Angstrom units of thickness of metal oxide have formed, the ratio of oxygen to metal vapor should decrease to zero after which pure metal alone condenses.

In this work the glass was first degreased by washing with ordinary handsoap and by rinsing in water and isopropynol. The glass was degassed by heating to between 540° and 650°C (1000° and 1200°F) for four minutes in a vacuum of 10^{-6} Torr. This treatment removed surface gases and probably also reduced the concentration of gases just below the surface of the glass as well.

At the end of the degassing cycle the glass was allowed to cool by radiation. At this point the partial pressure of H_2O and CO_2 is very low because of the "pumping" action of the liquid nitrogen trap. There is very likely a higher proportion of O_2 than in the atmosphere, which is desirable. More oxygen can be admitted and indeed was in the early work. But the result usually was a deposited layer of low density and strength. The weak films failed within the film thickness rather separate from the glass in the tensile test. To obtain a high-density film another procedure was used.

After the glass had cooled only 45 sec from the degassing temperature, a film 200 Å thick was deposited. The glass was immediately reheated to 537°C (1000°F) and held for three minutes. This probably allowed sintering and oxide formation in the metal film. Then the glass was allowed to cool for 30 sec after which a second layer was deposited on the first layer.

Within 30 sec after the second layer of aluminum was deposited on the glass a clean gold sphere was pressed against the metal film with a force of 240 g (8.5 oz), with a minimum of impact. The pressing force was removed and a separating force was applied. In four consecutive cases the test ended with the removal of a nugget of glass from the glass plate.

In two of the cases the separating force was found to approach 280 g (10 oz). In the other two cases the separating force was near 140 g (5 oz).

The stresses resulting from the tensile test cannot be determined with significant accuracy. However certain estimates can be made. The diameters of the cavities from which the glass nuggets were removed were about 5 mm (0.02 in). Thus for the four cases the average tensile stress in the contact area was between 1000 and 2000 psi.

Just as in the case of compressive contact, the stress distribution across the area of contact is not uniform. Johnson finds the maximum stresses in the adhesion case to be tensile and infinite.[5] McFarlane and Tabor in their work on adhesion of metals find the maximum adhesion stress to be at the rim of the contact area and it is considerably higher than the average stress.[6] Whatever the conclusions from theoretical considerations may be, it is logical to assume that the stresses in the contact region are not much greater than the simple tensile strength of the failed member, in this case the glass. The tensile strength of the type of microscope slides used was found to average about 20 000 psi, as determined by the standard bend test. The adhesion stresses must have been nearly 20 000 psi to initiate failure in the glass.

The tensile test shows that the gold–aluminum adhesion strength, the strength of the vapor deposited layer, and the aluminum–glass adhesion strength in this work exceeded 1000 psi and approached 20 000 psi. This is considerably higher than previously reported.

Other technological conclusions can be drawn.

a. Good adhesion can be accomplished between a vapor deposited metal film and a clean metal. No heating or rubbing is required, contact is the only requirement.

b. Dense and strong vapor deposited layers of aluminum can be obtained by sintering and oxide formation.

c. The production of adherent vapor deposited films of aluminum is critically dependent on the removal of adsorbed gases from the glass.

* Present address: Cavendish Laboratory, Cambridge, England.

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CsCl-Type Compounds in Binary Alloys of Rare-Earth Metals with Zinc and Copper*

C. C. Chao, H. L. Luo, and P. Duwez
W. M. Keck Laboratory of Engineering Materials, California Institute of Technology, Pasadena, California
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THE CsCl-type structure has been previously reported in alloys of copper with yttrium, gadolinium, and erbium,[1] and of zinc with lanthanum, cerium, and praesodymium.[2] The present investigation has uncovered five additional phases in copper–rare-earth alloys and nine in zinc–rare-earth alloys.

TABLE I. Lattice parameter of compounds of B2-type structure of rare-earth elements with copper and zinc.

Compound	Lattice-parameter (Å) Present work	Previous work
YCu		3.476±2[a]
SmCu	3.528±2	
GdCu		3.505 [a]
TbCu	3.480±4	
DyCu	3.460±3	
HoCu	3.445±2	
ErCu		3.432 [a]
TmCu	3.414±1	
YZn	3.577±3	
LaZn		3.759 [b]
CeZn		3.704 [b]
PrZn		3.678 [b]
NdZn	3.667±2	
SmZn	3.627±1	
GdZn	3.602±4	
TbZn	3.576±4	
DyZn	3.563±3	
HoZn	3.547±3	
ErZn	3.532±3	
TmZn	3.516±3	

[a] See Ref. 1.
[b] See Ref. 2.

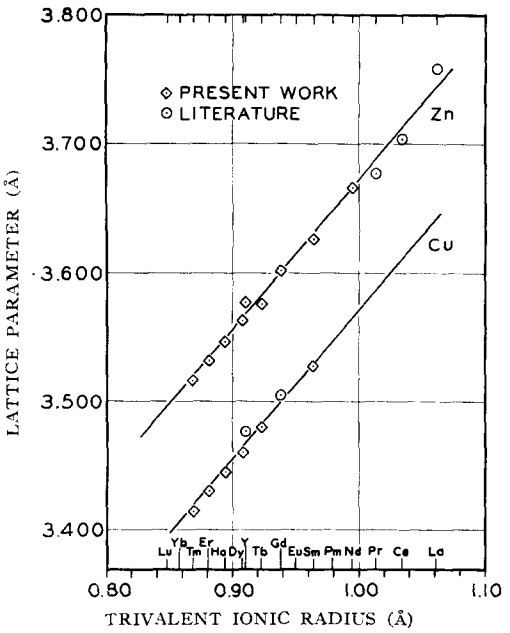

FIG. 1. Lattice parameters of CsCl-type phases vs trivalent ionic radii of the rare-earth metals.

The rare-earth metals were obtained from the American Potash and Chemical Corporation, except Gd, which was received from the Atomic Energy Commission and Y, from Michigan Chemical Corporation. All rare-earth metals were approximately 99.9% pure, and copper and zinc had a purity greater than 99.9%.

Alloys were prepared by the induction melting of stoichiometric amounts in tantalum crucibles under argon. For all the zinc alloys a very strong exothermic reaction took place. No such strong reaction was observed in copper alloys. All the alloys were stable in air at room temperature. Most of the phases reported in this investigation were found in alloys "as cast" without further heat treatment. For CuSm, however, the CsCl-type compound was found only after rapid cooling from the melt, a technique described in Ref. 3.

The structure of the alloys was investigated by x-ray diffraction using a Debye–Scherrer camera 114.6 mm in diameter and copper $K\alpha$ radiation with nickel filter. With the exception of some of the zinc alloys (ZnSm, ZnHo), the high angle lines of the x-ray diffraction pattern were not resolved. In these cases an average Cu $K\alpha$ wavelength (1.54178 Å) was used. Lattice parameters were obtained from extrapolation against the Nelson–Riley function. The lattice parameters measured in this investigation and those of the six phases previously reported are presented in Table I. In all cases, the superlattice diffraction line peaks typical of the CsCl structure were present in the diffraction patterns. As shown in Fig. 1, a linear relationship seems to exist between the lattice parameter of the compounds and the trivalent radii[4] of the rare-earth elements. Similar relationships were obtained earlier for NaCl-type compounds[5] and CsCl-type compounds[6] involving rare-earth metals. A clear explanation of these results has not yet been found.

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Significance of the Term "Zone Length" and the Ratio of Density of Solid to Liquid in the Mathematics of Zone Melting

W. G. PFANN
Bell Telephone Laboratories, Incorporated, Murray Hill, New Jersey
(Received 12 August 1963)

THIS note has two objectives: (1) to call attention to the significance for the zone-melting equations of the ratio (ρ_S/ρ_L) of the density of the solid to that of the liquid, and (2) to call attention to the proper interpretation of the term *zone length* in these equations. These two topics are related. They are of modest importance in solid–liquid zoning processes, but they have generally been overlooked by considering the ratio (ρ_S/ρ_L) to be unity. They are of transcendent importance in solid–vapor or liquid–vapor zoning processes because in these the density ratio (ρ_S/ρ_V) or (ρ_L/ρ_V) is very large.

The basic zone-melting equation, as given by Reiss[1] and Lord,[2] and earlier in a special form by Read[3] is:

$$(l/k)dC_n(x)=[C_{n-1}(x+l)-C_n(x)]dx. \tag{1}$$

Here $C_n(x)$ denotes the solute concentration in the nth pass at distance x from the first solid to form, l denotes zone length, and k denotes the distribution coefficient, defined as the ratio of the solute concentration in the freezing solid to that in the bulk liquid. Among the assumptions are: (1) the cross-sectional area is constant and unchanged by passage of the zone, and (2) $(\rho_S/\rho_L)=1$.

With assumption (2) made, the units in which solute concentrations are expressed have no effect on the equation. However, if $(\rho_S/\rho_L)\neq 1$, and if solute concentrations in liquid and solid are expressed as atoms or grams of solute per unit volume of solution, then the density ratio enters the equation. If $(\rho_S/\rho_L)\neq 1$, and if solute concentrations are expressed in weight fraction or atom fraction, then the density ratio does *not* enter the equation, provided that—and this is most important—the zone length l is understood to be the length of solid that was melted to form the zone. This is not necessarily the same as the length of the molten zone.

In the following, we illustrate these statements by deriving, for the two categories of units, the equations for the passage of a single molten zone through a charge of uniform concentration in the solid C_0. The right-hand side of Eq. (1) is equal to the change dS in the amount S of solute in the zone where, assuming $(\rho_S/\rho_L)=1$, S is given by:

$$S=[C_n(x)/k]l. \tag{2}$$

In Eq. (2), l denotes the volume of the zone, as the cross-sectional area of the charge does not enter into Eq. (1). Consider now a liquid zone at x, of length l, and of density greater than that of the solid. Allow it to advance a distance dx, as shown schematically in Fig. 1, without changing the cross-sectional area A_S, of the solid (for example, by tilting the charge at the proper angle[4]). The mean cross-sectional area A_L, of the zone is:

$$A_L=A_S\rho_S/\rho_L. \tag{3}$$

First, assume solute concentrations to be in atoms of solute per unit volume of solution. The amount of solute entering the zone at $(x+l)$ is

$$A_S dx C_0. \tag{4}$$

The amount of solute leaving the zone is

$$A_S dx C_n(x). \tag{5}$$

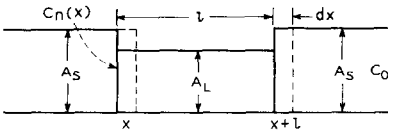

FIG. 1. Diagram for the passage of a single molten zone through a solid charge of uniform concentration.